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**(54) Title:** LITHOGRAPHIC APPARATUS AND DEVICE MANUFACTURING METHOD

**(57) Abstract:** A lithographic apparatus includes an illumination system for providing a beam of radiation and a support structure for supporting a patterning device. The patterning device serves to impart the beam with a pattern in its cross-section. The lithographic apparatus includes a substrate table for holding a substrate and a projection system for projecting the patterned beam onto a target portion of the substrate. The apparatus has a chuck system for supporting an object, such as the substrate or the patterning device, in the lithographic apparatus. The chuck system includes a chuck for supporting the object, a frame for supporting the chuck, and a chuck support structure for supporting the chuck relative to the frame. The chuck support structure includes at least one flexure element, which flexure element is flexible in at least one degree of freedom and is coupled to the chuck and the frame.

# Lithographic Apparatus and Device Manufacturing Method

## BACKGROUND OF THE INVENTION

Field of the Invention

**[0001]** The present invention relates to a lithographic apparatus and a device manufacturing method.

Brief Description of Related Art

**[0002]** A lithographic apparatus is a machine that applies a desired pattern onto a target portion of a substrate. Lithographic apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In that circumstance, a patterning device, such as a mask, may be used to generate a circuit pattern corresponding to an individual layer of the IC, and this pattern can be imaged onto a target portion (e.g. comprising part of, one or several dies) on a substrate (e.g. a silicon wafer) that has a layer of radiation-sensitive material (resist). In general, a single substrate will contain a network of adjacent target portions that are successively exposed. Known lithographic apparatus include so-called steppers, in which each target portion is irradiated by exposing an entire pattern onto the target portion in one go, and so-called scanners, in which each target portion is irradiated by scanning the pattern through the projection beam in a given direction (the "scanning"-direction) while synchronously scanning the substrate parallel or anti-parallel to this direction.

**[0003]** In a manufacturing process using a lithographic apparatus, the pattern has to be imaged on the substrate very accurately. The current lithographic projection apparatuses are commonly used to manufacture devices with typical dimensions in the micron or sub micron range. Hence, the pattern has to be imaged on the substrate with a corresponding accuracy.

**[0004]** It has been proposed to immerse the substrate in the lithographic projection apparatus in a liquid having a relatively high refractive index, e.g. water, so as to fill a space between the final element of the projection system and the substrate. The point of this is to enable imaging of smaller features since the exposure radiation will have a shorter wavelength in the liquid. (The effect of the liquid may also be regarded as

increasing the effective NA of the system and also increasing the depth of focus.) Other immersion liquids have been proposed, including water with solid particles (e.g. quartz) suspended therein.

**[0005]** However, submersing the substrate or substrate and substrate table in a bath of liquid (see for example US 4,509,852, hereby incorporated in its entirety by reference) means that there is a large body of liquid that must be accelerated during a scanning exposure. This requires additional or more powerful motors and turbulence in the liquid may lead to undesirable and unpredictable effects.

**[0006]** One of the solutions proposed is for a liquid supply system to provide liquid on only a localized area of the substrate and in between the final element of the projection system and the substrate using a liquid confinement system (the substrate generally has a larger surface area than the final element of the projection system). One way which has been proposed to arrange for this is disclosed in WO 99/49504, hereby incorporated in its entirety by reference. As illustrated in Figures 8 and 9, liquid is supplied by at least one inlet IN onto the substrate, preferably along the direction of movement of the substrate relative to the final element, and is removed by at least one outlet OUT after having passed under the projection system. That is, as the substrate is scanned beneath the element in a –X direction, liquid is supplied at the +X side of the element and taken up at the –X side. Figure 8 shows the arrangement schematically in which liquid is supplied via inlet IN and is taken up on the other side of the element by outlet OUT which is connected to a low pressure source. In the illustration of Figure 8 the liquid is supplied along the direction of movement of the substrate relative to the final element, though this does not need to be the case. Various orientations and numbers of in- and out-lets positioned around the final element are possible, one example is illustrated in Figure 9 in which four sets of an inlet with an outlet on either side are provided in a regular pattern around the final element.

**[0007]** Another solution which has been proposed is to provide the liquid supply system with a seal member which extends along at least a part of a boundary of the space between the final element of the projection system and the substrate table. Such a solution is illustrated in Figure 10. The seal member is substantially stationary relative to the

projection system in the XY plane though there may be some relative movement in the Z direction (in the direction of the optical axis). A seal is formed between the seal member and the surface of the substrate. Preferably the seal is a contactless seal such as a gas seal. Such as system with a gas seal is illustrated in Figure 11 and which is disclosed in European Patent Application No. 03252955.4 hereby incorporated in its entirety by reference.

**[0008]** In European Patent Application No. 03257072.3 the idea of a twin or dual stage immersion lithography apparatus is disclosed. Such an apparatus is provided with two stages for supporting the substrate. Leveling measurements are carried out with a stage at a first position, without immersion liquid, and exposure is carried out with a stage at a second position, where immersion liquid is present. Alternatively, the apparatus has only one stage.

**[0009]** For precise positioning and handling, in most known lithographic apparatuses, both non-immersion machines and immersion machines, the substrate is supported, and (optionally) moved, relative to other parts in the lithographic apparatus by a substrate table. The table has a chuck system which is provided with a chuck. The chuck has a support surface on which the supported object, e.g. the substrate, can be clamped, in order to support the object. Furthermore, the known lithographic apparatus can be provided with a mask table which supports a mask. The mask table may also have a chuck system, which includes a chuck on which the mask can be mounted.

**[0010]** For example, from United States Patent No. 6,353,271 a lithographic apparatus is known, which comprises a stage for precise positioning of a chuck in three orthogonal linear axes and in three orthogonal rotation axes. A substrate can be clamped on the chuck using an electrostatic force. The stage comprises a frame which supports the chuck. In this prior art document, the frame is implemented as a monolithic mirror block. The chuck is rigidly mounted on the monolithic mirror block. The monolithic mirror block is provided with mirrors that are part of an interferometer system that is used to determine the position of the chuck relative to other parts of the lithographic apparatus.

**[0011]** However, a drawback of the chuck system known from this prior art document is that the chuck may deform, for example due to heating or cooling during the

lithographic projection process. The deformation of the chuck can be transferred onto the frame or mirror block. Hence, the mirror block is deformed as well. This, inter alia, affects the accuracy of the interferometric measurements performed using the mirrors on the mirror block, which in turn affects the precision of positioning the substrate relative to the projection beam.

## SUMMARY

**[0012]** An aspect of the present invention is to provide an improved lithographic apparatus. More specific, it is an aspect of the present invention to provide a lithographic apparatus in which deformation of the frame due to deformation of the chuck is at least reduced.

**[0013]** According to an aspect of the invention, there is provided a lithographic apparatus comprising: a projection system constructed to project a beam of radiation onto a target portion of a substrate; a patterning device constructed to impart a cross-section of the beam of radiation with a pattern; and a chuck system including, a chuck constructed to hold one of the substrate and the patterning device; a frame constructed to hold the chuck; and a chuck support structure operable between the chuck and the frame, and constructed to support the chuck relative to the frame, the chuck support structure including a flexure element coupled between the chuck and the frame, the flexure element being flexible in at least one degree of freedom.

**[0014]** In such a lithographic apparatus, global deformation of the chuck, such as bow, warp, expansion, or compression, is at least partially not transferred to the frame, because the chuck support structure at least partially inhibits transfer of the deformation from the chuck to the frame. The chuck support structure comprises a flexure element which is coupled to the chuck and the frame and is flexible in at least one degree of freedom. Accordingly, in case of a deformation of the chuck, the flexure element will flex and at least a part of the deformation is not transferred to the frame.

**[0015]** In an embodiment of the invention, at least one of the at least one flexure elements is resistant to deformation in a plane parallel to a direction of movement of the frame. Thereby, a displacement of the frame in the direction in which the at least one

flexure element is rigid is transferred to the chuck, while a deformation of the chuck is absorbed by a flexure of the flexure element in the degree of freedom in which the flexure element is flexible.

**[0016]** In an embodiment of the invention, the chuck system further comprises at least one chuck support which supports the chuck with respect to the frame, and which chuck support extends in a spacing between the chuck and the frame. Thereby, deformation of the frame due to deformation of the chuck is reduced further, while the chuck is accurately positioned with respect to the frame, because changes in the chuck shape, such as expansion or deformation, can be received in the spacing, while the chuck is held in position relative to the frame by the chuck supports.

**[0017]** In an embodiment of the invention, the chuck support is resistant to deformation in at least one degree of freedom in which the flexure element is flexible. Thereby, the chuck is accurately held in position with respect to the frame, because the chuck support holds the chuck in position in one or more of the degrees of freedom in which the flexure element is flexible, while the flexure element fixates the position of the chuck in the other degrees of freedom.

**[0018]** In an embodiment of the invention, the chuck support is mechanically disconnected from the frame and/or the chuck. Thereby, the chuck is not mechanically connected to the frame, but may, for instance, be coupled using electro-static forces and may be replaced without a complex replacement operation.

**[0019]** In an embodiment of the invention, the frame has a recess in which the chuck is positioned. Because of the recess, the surface of the chuck, or the surface of the object supported by the chuck and the surface of the frame can be substantially at the same level. Thus, if the position of the surface of the frame is determined the position of the chuck surface or the object supported by the chuck can be derived as well in an uncomplicated manner.

**[0020]** In an embodiment of the invention, the lithographic apparatus further comprises a chuck deformation predicting device capable of predicting a deformation of the chuck in at least one degree of freedom; and a projection adjuster device connected to the chuck deformation measuring device, which projection adjuster device is arranged for

adjusting in response to a prediction signal outputted by the chuck deformation predicting device at least one of: a property of the projection beam, a position of a pattern in the patterned beam of radiation relative to the object or vice versa.

**[0021]** In such a lithographic apparatus, accurate corrections can be made, because the deformation of the chuck is not coupled to a deformation of the frame and accordingly the deformation can be predicted with a high degree of accuracy.

**[0022]** In an embodiment of the invention, the lithographic apparatus further comprises an illumination system for providing a projection beam of radiation; a support structure for supporting a patterning device, the patterning device serving to impart the projection beam with a pattern in its cross-section; and a substrate table for holding a substrate; and at least one of the support structure and the substrate table comprises at least one of the at least one chuck systems, for supporting the substrate and/or the patterning device.

**[0023]** In a lithographic apparatus according to this embodiment, the radiation beam can be projected with an increased accuracy onto the substrate, because deformation of the frames is reduced in the systems supporting elements which have a significant impact on the accuracy of projecting the radiation (i.e. the substrate and patterning device). Accordingly, the those elements can be position more precise with respect to each other and the minimal dimensions of the structures to be formed onto the substrate are improved.

**[0024]** According to a further aspect of the invention, there is provided a method of manufacturing a device, comprising: projecting a beam of radiation onto a target portion of a substrate; imparting a pattern to a cross-section of the beam of radiation to form a patterned beam using a patterning device; and supporting at least one of the substrate and the patterning device in a flexible manner by using a chuck system, the chuck system including a chuck to hold one of the substrate and the patterning device and a frame to hold the chuck, and providing flexible support in at least one degree of freedom between the chuck and the frame.

**[0025]** According to another aspect of the invention, a chuck system constructed to support an object in a lithographic apparatus, the chuck system comprising: a chuck

constructed to hold the object; a frame constructed to hold the chuck; and a chuck support structure operable between the chuck and the frame and constructed to support the chuck relative to the frame, the chuck support structure including a flexure element, the flexure element being coupled between the chuck and the frame, and the flexure element being flexible in at least one degree of freedom.

**[0026]** According to another aspect of the invention, a lithographic apparatus is provided comprising: means for projecting a beam of radiation onto a substrate; means for forming a patterned beam of radiation by imparting a cross-section of the beam of radiation with a pattern; and flexible means for supporting one of the substrate and the means for forming a patterned beam in a flexible manner to provide at least one degree of freedom.

**[0027]** It is desirable to provide an inexpensive substrate table.

**[0028]** It is desirable to provide an apparatus suitable for immersion lithography. In particular, to allow space for means for heating of the substrate table to compensate for cooling by evaporation of immersion liquid.

**[0029]** According to an aspect of the invention, there is provided a lithographic apparatus comprising: a substrate table comprising a frame for receiving a substrate support constructed to support a substrate; and a clamp on said frame for holding said substrate support substantially stationary relative to said frame; wherein parts of said clamp for holding said substrate support substantially stationary, in the plane perpendicular to the optical axis, relative to said frame are substantially mechanically decoupled from said frame in the direction of the optical axis.

**[0030]** According to an aspect of the invention, there is provided a lithographic apparatus comprising: a substrate table comprising a frame for receiving and supporting a substrate support which is constructed to hold a substrate; wherein said frame is arranged to support said substrate support in the direction of the optical axis by three mechanical hinges.

**[0031]** According to an aspect of the invention, there is provided a lithographic apparatus comprising: a substrate table; said substrate table comprising: a substrate support constructed for holding a substrate; and a frame for receiving said substrate

support; wherein said frame has a member for supporting said substrate support, said member being less stiff in the direction of the optical axis than said substrate support.

**[0032]** According to an aspect of the invention, there is provided a device manufacturing method comprising transferring a pattern from a patterning device onto a substrate, wherein said substrate is supported on a substrate support which is stiffer in the direction from which said pattern is transferred than a member of a frame on which said substrate support is held.

**[0033]** Although specific reference may be made in this text to the use of lithographic apparatus in the manufacture of ICs, it should be understood that the lithographic apparatus described herein may have other applications, such as the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid-crystal displays (LCDs), thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "wafer" or "die" herein may be considered as synonymous with the more general terms "substrate" or "target portion", respectively. The substrate referred to herein may be processed, before or after exposure, in for example a track (a tool that typically applies a layer of resist to a substrate and develops the exposed resist) or a metrology or inspection tool. Where applicable, the disclosure herein may be applied to such and other substrate processing tools. Further, the substrate may be processed more than once, for example in order to create a multi-layer IC, so that the term substrate used herein may also refer to a substrate that already contains multiple processed layers.

**[0034]** The terms "radiation" and "beam" used herein encompass all types of electromagnetic radiation, including ultraviolet (UV) radiation (e.g. having a wavelength of 365, 248, 193, 157 or 126 nm) and extreme ultra-violet (EUV) radiation (e.g. having a wavelength in the range of 5-20 nm), as well as particle beams, such as ion beams or electron beams.

**[0035]** The term "patterning device" or "patterning structure" used herein should be broadly interpreted as referring to a device or structure that can be used to impart a projection beam with a pattern in its cross-section such as to create a pattern in a target portion of the substrate. It should be noted that the pattern imparted to the projection

beam may not exactly correspond to the desired pattern in the target portion of the substrate. Generally, the pattern imparted to the projection beam will correspond to a particular functional layer in a device being created in the target portion, such as an integrated circuit.

**[0036]** Patterning devices may be transmissive or reflective. Examples of patterning devices include masks, programmable mirror arrays, and programmable LCD panels. Masks are well known in lithography, and include mask types such as binary, alternating phase-shift, and attenuated phase-shift, as well as various hybrid mask types. An example of a programmable mirror array employs a matrix arrangement of small mirrors, each of which can be individually tilted so as to reflect an incoming radiation beam in different directions; in this manner, the reflected beam is patterned. In each example of patterning device, the support structure may be a frame or table, for example, which may be fixed or movable and which may ensure that the patterning device is at a desired position, for example with respect to the projection system. Any use of the terms "reticle" or "mask" herein may be considered synonymous with the more general term "patterning device".

**[0037]** The term "projection system" used herein should be broadly interpreted as encompassing various types of projection system, including refractive optical systems, reflective optical systems, and catadioptric optical systems, as appropriate for example for the exposure radiation being used, or for other factors such as the use of an immersion fluid or the use of a vacuum. Any use of the term "lens" herein may be considered as synonymous with the more general term "projection system".

**[0038]** The illumination system (IL) may also encompass various types of optical components, including refractive, reflective, and catadioptric optical components for directing, shaping, or controlling the projection beam of radiation, and such components may also be referred to below, collectively or singularly, as a "lens".

**[0039]** The lithographic apparatus may be of a type having two (dual stage) or more substrate tables (and/or two or more mask tables). In such "multiple stage" machines the additional tables may be used in parallel, or preparatory steps may be

carried out on one or more tables while one or more other tables are being used for exposure.

**[0040]** The lithographic apparatus may also be of a type wherein the substrate is immersed in a liquid having a relatively high refractive index, e.g. water, so as to fill a space between the final element of the projection system and the substrate. Immersion liquids may also be applied to other spaces in the lithographic apparatus, for example, between the mask and the first element of the projection system. Immersion techniques are well known in the art for increasing the numerical aperture of projection systems.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0041]** Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, and in which:

**[0042]** FIGS. 1a and 1b depict respectively a reflective and a transmissive lithographic apparatus according to an embodiment of the invention;

**[0043]** FIG. 2 shows a perspective, partially exploded view of an example of a chuck system according to an embodiment of the invention;

**[0044]** FIG. 3 shows a cross-sectional view of the example of a chuck system of FIG. 2;

**[0045]** FIG. 4 shows a cross-sectional view of the example of a chuck system of FIG. 2 with the chuck in a deformed state;

**[0046]** FIG. 5 shows a cross-sectional view of another example of a chuck system according to an embodiment of the invention, different from the example of FIGS. 2-4;

**[0047]** FIG. 6 shows a cross-sectional view of another example of a chuck system according to an embodiment of the invention different from the example of FIGS. 2-4 and the example of 5;

**[0048]** FIGS. 7A-C show examples of flexure elements suitable for use in an example of a chuck system according to an embodiment of the invention;

**[0049]** FIGS. 8 and 9 depict a liquid supply system used in a prior art lithographic projection apparatus;

**[0050]** FIG. 10 depicts a liquid supply system according to another prior art lithographic projection apparatus;

**[0051]** FIG. 11 depicts a liquid supply system according to another lithographic projection apparatus;

**[0052]** FIG. 12 depicts, in plan, a substrate table in accordance with the present invention;

**[0053]** FIG. 13 depicts the substrate table of FIG. 12, in cross-section along line 13-13 in FIG. 12;

**[0054]** FIG. 14 depicts, in plan, a substrate table of another embodiment of the present invention;

**[0055]** FIG. 15 depicts the substrate table of FIG. 14 in cross-section along line 15-15 in FIG. 14;

**[0056]** FIG. 16 depicts a possible construction of a rib of the mirror block of FIG 13 or 15;

**[0057]** FIG. 17 depicts the burl map (or pattern) of a substrate support useable with the mirror block of FIGS. 13 or 15; and

**[0058]** FIG. 18 depicts a substrate table of the prior art.

## DETAILED DESCRIPTION OF ILLUSTRATED EMBODIMENTS

**[0059]** Figures 1a und 1b respectively schematically depict a reflective and a transmissive lithographic apparatus according to an embodiment of the invention. The present invention can be used in either type of apparatus. In the case of the transmission type, either in an immersion machine or in a non-immersion machine. The apparatuses comprise: an illumination system (IL) (illuminator) IL for providing a projection beam PB of radiation (e.g. UV or EUV radiation); a first support structure (e.g. a mask table) MT for supporting a patterning device (e.g. a mask) MA and connected to first positioning structure PM for accurately positioning the patterning device with respect to item PL; a substrate table (e.g. a wafer table) WT for holding a substrate (e.g. a resist-coated wafer) W and connected to second positioning structure PW for accurately positioning the substrate with respect to item PL; and a projection system (e.g. a reflective projection

lens) PL for imaging a pattern imparted to the projection beam PB by patterning device MA onto a target portion C (e.g. comprising one or more dies) of the substrate W.

**[0060]** In Fig. 1a the apparatus is of a reflective type (e.g. employing a reflective mask or a programmable mirror array of a type as referred to above). In Fig. 1b the apparatus is of a transmissive type (e.g. employing a transmissive mask).

**[0061]** The illuminator IL receives a beam of radiation from a radiation source SO. The source and the lithographic apparatus may be separate entities, for example when the source is a plasma discharge source. In such cases, the source is not considered to form part of the lithographic apparatus and the radiation beam is generally passed from the source SO to the illuminator IL with the aid of a radiation collector comprising for example suitable collecting mirrors and/or a spectral purity filter. In other cases the source may be integral part of the apparatus, for example when the source is a mercury lamp. The source SO and the illuminator IL, may be referred to as a radiation system.

**[0062]** The illuminator IL may comprise an adjuster that adjusts the angular intensity distribution of the beam. Generally, at least the outer and/or inner radial extent (commonly referred to as ? -outer and ? -inner, respectively) of the intensity distribution in a pupil plane of the illuminator can be adjusted. The illuminator provides a conditioned beam of radiation, referred to as the projection beam PB, having a desired uniformity and intensity distribution in its cross-section.

**[0063]** The projection beam PB is incident on a patterning device, illustrated in the form of the mask MA, which is held on the mask table MT. Being reflected or transmitted by the mask MA, the projection beam PB passes through the lens PL, which focuses the beam onto a target portion C of the substrate W. With the aid of the second positioning structure PW and position sensor IF2 (e.g. an interferometric device), the substrate table WT can be moved accurately, e.g. so as to position different target portions C in the path of the beam PB. Similarly, the first positioning structure PM and position sensor IF1 can be used to accurately position the mask MA with respect to the path of the beam PB, e.g. after mechanical retrieval from a mask library, or during a scan. In general, movement of the object tables MT and WT will be realized with the aid of a long-stroke module (coarse positioning) and a short-stroke module (fine positioning),

which form part of the positioning structures PM and PW. However, in the case of a stepper (as opposed to a scanner) the mask table MT may be connected to a short stroke actuator only, or may be fixed. Mask MA and substrate W may be aligned using mask alignment marks M1, M2 and substrate alignment marks P1, P2.

**[0064]** The depicted apparatus can be used in the following preferred modes.

**[0065]** In step mode, the mask table MT and the substrate table WT are kept essentially stationary, while an entire pattern imparted to the projection beam is projected onto a target portion C in one go (i.e. a single static exposure). The substrate table WT is then shifted in the X and/or Y direction so that a different target portion C can be exposed. In step mode, the maximum size of the exposure field limits the size of the target portion C imaged in a single static exposure.

**[0066]** In scan mode, the mask table MT and the substrate table WT are scanned synchronously while a pattern imparted to the projection beam is projected onto a target portion C (i.e. a single dynamic exposure). The velocity and direction of the substrate table WT relative to the mask table MT is determined by the de-magnification and image reversal characteristics of the projection system PL. In scan mode, the maximum size of the exposure field limits the width (in the non-scanning direction) of the target portion in a single dynamic exposure, whereas the length of the scanning motion determines the height (in the scanning direction) of the target portion.

**[0067]** In another mode, the mask table MT is kept essentially stationary holding a programmable patterning device, and the substrate table WT is moved or scanned while a pattern imparted to the projection beam is projected onto a target portion C. In this mode, generally a pulsed radiation source is employed and the programmable patterning device may be updated after each movement of the substrate table WT or in between successive radiation pulses during a scan. This mode of operation can be readily applied to maskless lithography that utilizes programmable patterning devices, such as a programmable mirror array of a type as referred to above.

**[0068]** Combinations and/or variations on the above described modes of use or entirely different modes of use may also be employed.

[0069] As can be seen from Figure 18, the substrate table WT of a conventional lithographic projection apparatus comprises a substrate support SS (chuck) and a frame in the form of a mirror block MB. The substrate support SS is placed on a top surface 1102 of the mirror block MB and is held in place by a vacuum source VAC. The substrate support SS is usually a so called “pimple table” or “burl table”. This is because a series of projections in combination with vacuum areas on the upper and lower surfaces of the substrate support SS allow a partial vacuum to be formed between the top surface 1102 of the mirror block MB and the substrate support SS and between the substrate support SS and the substrate W. The force generated by the vacuum is enough to hold the substrate support SS in place on the mirror block MB and the substrate W on the substrate support. The burls ensure a stiff fixation of the substrate W on the substrate support SS and of the substrate supports on the mirror block MB. Because the inferometer mirrors 1150 are positioned on the mirror block MB and the position of the substrate W is measured through those inferometer mirrors 1150, it is important that the mirror block MB does not distort due to the clamping forces. For this reason, in this design, member 1110 of the mirror block MB on which the substrate support SS is placed is of a far higher internal stiffness than the substrate support SS, particularly in the direction of the optical axis (z axis). This is achieved by ensuring that the thickness of the member 1110 is far greater than that of the substrate support SS. For this reason, in this design, the top surface 1102 of the mirror block MB must be polished to a very high surface flatness because it is the substrate support SS which deforms to the shape of the top surface 1102 of the mirror block MB and any distortions can thereby be transmitted to the substrate W. Typically the mirror block MB is machined from a low co-efficient of expansion material such as Zerodur (RTM). The solid mirror block may have holes machined in it to reduce the mass. A lower recess 1101 in the bottom surface of the mirror block MB is large enough to house actuator 1100 which is for positioning the substrate table WT. The substrate table of the present invention allows the top surface of the mirror block MB to have a lower surface finish specification and allows the substrate support SS to be stiffer so that heating (or cooling) means can be added which inevitably result in the substrate support becoming thicker.

[0070] In the example of Fig. 1a, the substrate table WT is provided with chuck 120 on which the substrate W is clamped. The chuck 120 and the part of the substrate table WT which supports the chuck 120 are part of a chuck system according to an embodiment of the invention, such as for example the chuck system 100 shown in figs. 2-4. In the example of Fig. 1a, the chuck system 100 is provided on the substrate table WT for support of the substrate W. However, a chuck system according to an embodiment of the invention may likewise be used to support other objects in a lithographic apparatus, such as the patterning device (e.g. the retticle or mask) and be provided on the mask table MT, for example.

[0071] FIG. 2 schematically shows an example of a chuck system 100 suitable for use in the example of FIG. 1a. In this example, the chuck system 100 comprises a frame 110, which may for instance be a part of the substrate table WT in the example of FIG. 1a or the mirror block MB of FIG. 18. In this example, the frame 110 is implemented as a mirror block and is provided with a number of mirrors 111 at different sides of the frame 110, which may be used in interferometric measurements to determine the position or the tilt of the frame 110, for example.

[0072] In this example, the frame 110 is provided with a driving device 113, arranged for positioning the frame 110 relative to other parts of the lithographic apparatus 1. The driving device 113 may for example comprise the long stroke and short stroke module as mentioned before.

[0073] The chuck system 100 further comprises a chuck 120 or a substrate support. The chuck 120 has an object surface 121 on which an object, such as a wafer or a mask, may be mounted and clamped using a, not shown, clamping device. The clamping device may for example be an electrostatic clamping device which exerts an electrostatic force on the substrate or a vacuum system which provides a vacuum between the chuck and the substrate and thus exerts a vacuum force on the substrate or another type of clamping device. It should be noted that clamping devices for a chuck are generally known in the art and for the sake of brevity are not described in further detail.

[0074] In this example, in use, the object surface 121 is substantially horizontal and the substrate is vertically supported by the chuck 120. However, it is likewise

possible to provide a chuck which has a substantially vertical object surface. A suitable shape for the chuck 120 may be rectangular for supporting masks or disk-shaped for supporting substrates. A chuck for supporting substrates may have a suitable diameter, for example between 10 and 45 cm. However, aspects of the invention are not limited to a specific shape or size and other shapes and sizes are likewise possible.

**[0075]** In the shown examples, the frame 110 further has a recess 112, in which the chuck 120 is positioned. Because of the recess 112, the surface 121 of the chuck 120, or the surface of the object supported by the chuck 120 and, what may be denoted as the top-surface of the frame 110 in the example of FIG. 2 can substantially be at the same level. Thus, if the position of the surface of the frame is determined, using the mirrors 111 for example, the position of the chuck 120 can easily be derived as well.

**[0076]** The chuck 120 is supported relative to the frame 110 by a chuck support structure 114 in a chuck support region of the frame 110. The chuck support structure 114 comprises a flexure element 130 (or membrane) which is flexible in at least one degree of freedom. The flexure element 130 is connected to the frame 110 and the chuck 120. The flexure element holds the chuck 120 in position with respect to the frame 110, and is deformable in at least one degree of freedom.

**[0077]** As is illustrated in FIG. 3, in a normal state, the chuck 120 is flat. However, during operation of the lithographic apparatus 1, the chuck 120 may deform. This deformation may for example be caused by thermal deformation of the substrate W which is clamped on the chuck 120 or heating of the chuck 120 itself, which causes a bending of the chuck 120. FIG. 4 shows the chuck 120 in a spherically deformed state. As seen in FIG. 4, the deformation causes the chuck 120 to exert a force on the flexure element 130. Due to the force the flexure element 130 deforms in the dimension in which it is flexible, but the force exerted by the chuck 120 is not transferred to the frame 110. Thus, the frame 110 is not deformed by the chuck 120. Accordingly, if the frame 110 is used for performing measurements, such as interferometrics position or tilt measurements using the mirrors 111 as shown in Fig. 2, the measurements are not affected by a deformation of the chuck 120.

**[0078]** In the examples shown, the flexure element 130 is deformable in at least one degree of freedom while substantially rigid in at least one other degree of freedom. Thereby, changes in position or shape in the direction in which the flexure element 130 is flexible are not transferred from the chuck 120 to the frame 110 or vice versa, while a displacement of the frame 110 in the direction in which the flexure element 130 is rigid is transferred of to the chuck 120. Thus, an accurate positioning of the chuck 120 can be obtained while transfer of a chuck deformation to the frame 110 and rotation of the chuck 120 around a vertical axis are prevented.

**[0079]** The flexure element(s) 130 may for example be rigid in a direction parallel to a direction of movement of the frame 110. For instance in FIG. 2, the flexure element 130 is substantially rigid in the plane parallel to the with axes x and y in FIG. 2, while flexible perpendicular to this plane, in the direction of the z-axis. The frame 110 can be moved in directions parallel to the plane defined by the axis x and y in FIG 2 by the driving device 113, that is substantially parallel to the surface 121 of the chuck 120 on which the supported object is mounted. Thus, when the frame 110 is moved in the x and/or y direction, the movement is transferred to the chuck 120 substantially at the same moment, while deformation of the chuck 120 are absorbed by flexing of the flexure element 130 in the z-direction.

**[0080]** The chuck system 100 may be provided with further positioning structures for keeping the chuck 120 in position with respect to the frame 110, such as electronic, magnetic or electro-magnetic sensor actuator systems for instance. Such positioning are generally known in the art of lithographic apparatuses and may for instance comprise Lorentz actuators, piezo-electric actuators or otherwise.

**[0081]** In the example of FIGs. 2-4, for holding the chuck 120 in position with respect to the frame 110, the chuck support structure 114 further comprises one or more chuck supports, in figs. 2-6 shown as struts 122, which support the chuck 120 with respect to the chuck support region of the frame 110, and hold the chuck 120 at a distance from the frame 110. A spacing is therefore present between the chuck 120 and the frame 110. Because of the spacing, expansion and/or deformation of the chuck 120 does not affect the frame 110, since such changes of the chuck 120 are received in the spacing.

**[0082]** In the example of FIGs. 2-4, the struts 122 are spike-shaped rigid extensions of the chuck 120 with a point-shaped end facing towards the frame 110. The struts 122 preferably form an integral part of the chuck 120 and are not connected to the frame 110. Thus, the chuck 120 and struts 122 form a self-supporting structure which is in contact with the frame 110 at the point-shaped ends of the struts 122 only. Thereby, the mechanical contact between the chuck 120 and the frame 110 is minimised and accordingly, transfer of deformation between the chuck 120 and the frame 110 is prevented.

**[0083]** However, the struts 122 may also be connected to the frame 110 or be connected to the flexure element 130 only, as in the example of FIG. 5, for instance. In such case, the chuck 120 is not mechanically connected to the frame 110 and may be replaced without a complex replacement operation.

**[0084]** In the example of FIGs. 2-4, the struts 122 extend through holes 123 formed in the flexure element 130 and the struts 122 are in contact with the frame 110 by their point-shaped ends. In the example of fig. 5, the struts 122 are positioned between the flexure elements 130 and the chuck 120 and not in contact with the frame 110.

**[0085]** In the example of FIGs. 2-4, the chuck 120 is provided with three struts 122 provided at the side 123 of the chuck 120 which faces the frame 110. Aspects of the invention are however not limited to this number of struts. The struts 122 are positioned at equal distances in a circumferential direction of the disk-shaped chuck 120. The struts 122 extend, in this example, through holes provided in the flexure element 130 towards the frame 110. The chuck 120 thus rests in a vertical direction on the struts 122.

**[0086]** Because three struts 122 are present, the chuck 120 is supported in the vertical direction in a statically determined manner. Thereby, tilting of the chuck 120 around a horizontal axis with respect to the frame 110 is prevented. Tilting of the chuck 120 can also be prevented by a chuck support structure which supports the chuck in a statically overdetermined manner, such as by four or more struts positioned at equal distances in a circumferential direction or otherwise.

**[0087]** The chuck support structure 114 may also connect the frame 110 to the chuck 120 in a kinematically determined or overdetermined manner in other dimensions

to prevent rotation or tilt in other directions. To that end, the chuck support structure 114 may, as in the example of FIGS. 2-4, comprise a flexure element 130 which is substantially rigid in at least one dimension. Also, struts may be provided which are rigid in a direction in which the flexure element 130 is flexible, to provide a good fixation of the chuck 120, while maintaining the deformation inhibition provided by the flexure element 130.

**[0088]** In the example of FIGs. 2-4, the flexure element 130 extends, at least partially, substantially completely in the spacing between the chuck 120 and the frame 110. Thereby, the footprint of the chuck system 100 is reduced because the frame area occupied by support structure 114 at least partially coincides with the frame area occupied by the chuck 120.

**[0089]** In the example of FIGs, 2-4, the flexure element 130 extends along substantially the whole side of the chuck 120 facing the frame 110. However, the flexure element 130 may also be implemented differently. For instance in the example of FIG. 5, the chuck support structure 114 comprises two or more separate leaf springs 130, each connected with a first leaf end 1310 of the leaf spring to the frame 110 and with a second leaf end 1320 to the chuck 120, while the second leaf ends 1320 are at a distance from each other.

**[0090]** In the example of FIG. 6, the chuck 120 is attached by a number of flexure elements 130 to the frame 110. A first flexure element 130 supports the chuck 120 in a vertical direction with respect to the frame 110, whereas a second flexure elements 131 are attached to the sides of the chuck 120. The second flexure elements 131 prevent tilting of the chuck 120 around a horizontal axis and provide further stability to the chuck 120. The first flexure elements 130 may be regarded as chuck supports which are resistant to deformation in the vertical direction and flexible in one or more other dimensions.

**[0091]** FIGS. 7A-D show some examples of leaf spring configurations suitable for implementation as a flexure element in a chuck system according to an embodiment of the invention.

**[0092]** The leaf spring 130A of FIG. 7A has an annular shape with a inner circumferential edge 1330 and an outer circumferential edge 1340. The leaf spring 130A is provided with slots 1350 extending in a radial direction from both edges 1330,1340. The leaf spring 130A is connected at the inner circumferential edge 1330 to the chuck 120 and can be connected to the frame 110 at the outer circumferential edge 1340. As shown in fig. 7A, the spring 130A can be provided with holes 123 in which struts 122 can extend.

**[0093]** FIG. 7B shows a configuration of a flexure element, comprising of a plurality, in this example four, separate leaf springs 130B positioned in a radial arrangement with a spacing in the circumferential direction between the leaf springs 130b. The radially inward projecting ends of the leaf springs 130B are connected to the chuck 120, while the radially outward projecting ends of the springs 130B can be connected to the frame 110. The struts 122 are positioned in the spacing between the springs 130B.

**[0094]** FIG. 7C shows a perspective view of a chuck 120 with leaf springs 130C connected with one end 1301 to a side 124 perpendicular to the support surface 121 of the chuck 120 and connectable with another end 1300 to the frame 110. The leaf springs 130C extend from the circumference of the chuck 120 in a tangential direction. The leaf springs 130C are locally weakened by cut-aways 1303, in order to provide the leaf spring 130C with flexibility in a traverse direction.

**[0095]** It should be noted that the flexure element 130 may also be implemented in a different manner than shown in the figures and for example comprise an elastic membrane or otherwise. The flexure element 130 may for example be may of a material similar to the material of at least one of the chuck 120 and the frame 110 are manufactured from. Such a flexure element has characteristics similar to the characteristics of other parts of the chuck system 100 and thus differing conditions affect different parts of the chuck system 100 in a corresponding manner. However, the flexure element 130 may also be made of a different material.

**[0096]** Alternatively, the flexure element 130 may be connected to the frame 110 and the chuck 120 by any connection suitable for the specific implementation. For

instance, if the lithographic apparatus uses EUV radiation, the flexure element 130 may be clamped by an electro-static clamping device to the frame 110. However, other connecting techniques such as gluing, welding or otherwise may likewise be used.

**[0097]** Because of the flexure element 130, the deformation of the chuck 120 and/or the substrate W mounted on the chuck 120 does not deform the frame 110. Thereby, the deformation of the substrate W and/or the chuck 120 is not dependent on the properties of the frame 110. Hence, the deformation of the substrate W and/or the chuck 120 may be predicted with a large degree of accuracy for different types of chuck systems.

**[0098]** As is schematically indicated in FIG. 2, the chuck system 100 may be provided with a chuck deformation prediction device 140. In the example of FIG. 2, the prediction device 140 comprises a deformation measuring device which can measure, with a sensor 141, a quantity which is related to a deformation of the chuck 120 and/or the substrate W in at least one degree of freedom, such as the temperature, the exposure energy of the radiation incident on the substrate W, the number of preceding substrates illuminated in the lithographic apparatus or another measured quantity, the deformation itself.

**[0099]** The sensor 141 can output a signal representing a value of the measured quantity to a calculator 142 which calculates a deformation of the chuck 120 and/or the substrate W from the measured quantity. The calculator 142 may for example be provided with a memory in which reference values for the deformation and the measured quantity are stored and a search device which looks-up the deformation corresponding to the measured value. The calculator may then output a deformation signal which represents a property the calculated deformation, such as the curvature of the chuck 120 for example, to an actuator 143. The actuator 143 may in response to the deformation signal adjust one or more properties of the projection beam, such as for example the magnification or the translation of the projected pattern perpendicular to the optical axis, e.g. parallel to the plane of the supported object or rotation of the projected pattern around the optical axis.

[00100] The chuck deformation prediction device 140 may also be implemented differently, and for example comprises a processor device which based on data stored in a memory predicts a deformation of the chuck and provides a prediction signal to the actuator 143 without actual measurement to the chuck 120, or any other suitable configuration.

[00101] A difficulty with immersion lithography is that immersion liquid inevitably remains on the surfaces of the substrate after exposure. This residue will evaporate and as a result the temperature of the substrate and substrate support will reduce. This is undesirable and a solution to this problem is to provide heating means (by way of hot water, for example) to the substrate support.

[00102] One of the objects of the present invention is to provide a frame or mirror block MB (which is moveable) which does not require the top surface 1102 to be polished to a high degree, thereby making the mirror block MB less expensive. Also, in immersion lithography, it has been found necessary to make the substrate support SS thicker (resulting in higher thermal mass) so that fluid warming of the substrate support SS can be incorporated. This is necessary because of evaporation of immersion liquid of the top surface of the substrate W can lead to cooling of the substrate W. The heating in the substrate support SS is intended to compensate for this reduction temperature of the substrate W. In order to provide such heating to the substrate support SS it is necessary, from an engineering point of view, to make the substrate support SS thicker. For I-line systems the substrate can get too hot and so liquid cooling of the substrate support SS is also useful. Again the substrate support SS will need to be made thicker in order to accommodate heat transfer liquid channels. The problem with making the substrate support SS thicker using the mirror block MB of Figure 18 is that this could result in distortion of the mirror block MB because of the increased stiffness of the substrate support. Distortion of the mirror block MB is to be avoided at all costs as this would prevent accurate measurement of the position of the substrate W because of interference with the mirrors 1150 through deformation leading to the mispositioning of the substrate W. Also the thickness of the substrate support SS is kept as low as possible to reduce the

"abbe-arm-error" due to the height difference between the position where the interferometers INF measure the position and the actual image is focused.

**[00103]** Figures 12 and 13 show an embodiment of the substrate table which deals with the two issues in the foregoing paragraph. The design is partly constrained by the desire to make the mirror block MB and substrate support SS backwards compatible, such that previously non immersion lithographic apparatus can be converted to an immersion apparatus without the need for whole scale re-design of the support structure. Thus, the overall height of the mirror block MB remains substantially the same as that of the prior art mirror block MB illustrated in Figure 18 and the actuator 1100 positioning the mirror block MB is of the same design and can fit in a cavity 1101 in the middle of the mirror block MB. This need not however be the case for other designs.

**[00104]** Figure 12 is a plan illustration of the mirror block of the first embodiment and Figure 13 is a cross-sectional view taken through line 13-13 in Figure 12. The top surface 1102 of the mirror block MB has a recess 1105 formed in it. Preferably the recess 1105 is deep enough so that the top surface of the substrate support SS is substantially co-planar with the top surface 1102 of the mirror block MB when the substrate support SS is positioned within the recess 1105. However, this need not be the case and, for example, it may be that for backwards compatibility it is necessary for the top of the substrate support SS to protrude above the top of the mirror block MB. More precisely, the relative sizes of the substrate support SS and recess 1105 are arranged such that the top surface of a substrate W placed onto the substrate support SS and the top surface of a cover plate (not illustrated) placed over the top surface of the mirror block 1102, are substantially co-planar.

**[00105]** The member 1110 beneath the substrate support SS at the bottom of the recess 1105 of the mirror block MB is machined such that it is relatively quite thin so that its stiffness in the z direction (the direction of the optical axis) is far less than the stiffness of the substrate support SS. The member 1110 can be described as a membrane, that is a member which is stiff in the plane and compliant in the out-of-plane directions. The ratio of stiffness of the substrate support to the member 1110 is preferably at least 10:1, more preferably 20:1 and more preferably at least 30:1 and more preferably at least

40:1, and most preferably at least 100:1. Ensuring such a stiffness ratio is advantageous because when a vacuum is applied to the underside of the substrate support SS (in the same way as the substrate support SS of Figure 18 described above) it is the member 1110 which is sucked up onto the underside of the substrate support SS and deformed to the shape of the substrate support SS rather than vice versa. In this way it is also possible to manufacture the top surface of member 110 to a less high degree of surface finish than previously as uneveness in the surface will not be transmitted to the substrate W. During clamping of the substrate support SS by the evacuating means in member 1110, member 1110 will deflect to contact with the undersurface of the substrate support SS. It is the member 1110 part of the mirror block which clamps the substrate support SS in the x y plane. It is this large contact surface area which provides the clamping force between the mirror block MB and the substrate support SS to prevent the substrate support SS from moving in the x y plane during accelerating of the mirror block MB in the x y direction.

**[00106]** The substrate support SS is supported by projections 1130 extending above the top surface of the member 1110. The projections 1130 are stiff in the z direction, contrary to the remainder of the member or membrane 1110. This is achieved by providing three fins or rib structures 1120 in the mirror block MB. These fins 1120 are connected to the circumferential surface of lower recess 1101 in which actuator 1100 is positioned along each side. Thus, the fins 1120 have a high stiffness, particularly in the z direction, and can support the weight of the substrate support SS when the evacuating holding means are actuated. It is necessary for the projections 1130 to interact with the bottom surface of the substrate support SS in a mechanical way equivalent to a hinge. In fact, it is not important for each of the projections 1130 to be of exactly equal height as a slight tilt of the substrate support SS, as long as this is known (and it can be easily measured), can be compensated for during exposure. Thus, machining of the member 1110 and fins 1120 is relatively inexpensive because a high surface finish or very high accuracy is not required. Alternatively the projections 1130 could be formed on the substrate support SS and would need to be aligned with the fins 1120 when the substrate support SS is placed on the mirror block MB.

[00107] The way in which the projections 1130 and the substrate support SS can be arranged to interact with each other in the way of a mechanical hinge is described below with reference to Figures 16 and 17.

[00108] It should be noted that the evacuating holding means could also be any other form of clamp, for example an electrostatic clamp and could take any other form of geometry.

[00109] With this design of mirror block it is possible to use a thicker (and therefore stiffer in the vertical direction) substrate support SS so that the mirror block MB may be used in immersion lithography because heating means, in particular fluid or liquid heating means, can be provided to the substrate support SS.

[00110] During immersion, the relatively stiff substrate support SS supports the substrate which may expand and contract due to thermal variation in the x y directions without deforming the mirror block MB. In the z direction the mirror block MB is much stiffer than the substrate support SS so that the global substrate support position will remain constant. Any heat flux from the substrate support SS to the mirror block MB is minimized because of the large thermal resistance of the mechanical hinges described below. Thus thermal size variations only occur in the substrate support SS and depend on the physical properties of the substrate support SS. Therefore any size variations can be predicted based on a knowledge of the temperature of the substrate support SS (e.g. obtainable using a sensor or predictable based on dose level, ambient temperature etc.) and the physical properties of the material from what it is made. These systematic errors can be compensated for by x y position offsets in the position control loop that controls the x y position of the mirror block. Furthermore, exposure settings can also be adjusted (e.g. magnification in x y etc.). Positional corrections in the z direction are also possible.

[00111] A further alternative embodiment of substrate table WT is illustrated in Figures 14 and 15 which are equivalent to Figures 12 and 13. In Figures 14 and 15 the member 1110 is not thin to reduce its stiffness but is rather thicker so that some stiffness would remain in the z direction were it not for a plurality of slits 1205 formed as through-cuts in the member 1110. The slits 1205 are effective to decouple the (vacuum)

clamp for holding the substrate support SS in the x y plane from the mirror block in the z direction such that defects in the top surface of the member 1110 or in the bottom surface of the substrate support SS are not transmitted to the mirror block MB. Thus, the theory of providing a clamp with parts for holding the substrate support SS in the x y plane which parts are decoupled from the mirror block MB in the z direction are the same for both embodiments. The slits 1205 illustrated in Figure 14 are illustrative only and any pattern of slits may be used which have the effect of de-coupling the member 1110 from the mirror block in the z direction.

**[00112]** Figures 16 and 17 illustrate two ways in which the contact between the three projections 1130 and the bottom surface of the substrate support SS can be arranged to act as hinges (i.e. to allow substantially free rotation around the x and y axes as if point contact occurred at only three discrete positions) or near hinges which have a small rotational stiffness.

**[00113]** In Figure 16, it can be seen that the fin 1120 does not project above the membrane along its whole width but only has a central projection 1130. Cut-outs 1207 are provided in the fins 1120 beneath the member 1110 either side of projection 1130. The cut-outs leave only a centre portion of the fin 1120 material 1209 directly beneath the projection 1130. This allows the top surface of the projection 1130 to rotate around the x and y axes because the amount of material 1209 left in the middle between the cut-outs 1207 has low rotational stiffness about the x and y axes.

**[00114]** An alternative way of providing three effective mechanical hinges for support of the substrate support SS is illustrated in Figure 17. Here the fins 1120 project above the top surface of the member 1110 along their entire width. However, by designing the pattern or area of burls (or pimples or projections) on the bottom of the substrate support SS as is illustrated in cross hatching in Figure 17, it is possible to support the substrate support SS on the top surface of the fins 1120 effectively at three hinge points 1212. This is accomplished by providing only a few burls in the region 1212 of the middle of each of the projecting fins 1120 so that a small area of contact is presented to the fins by the substrate support SS at the centre of the top surface of each

fin. Clearly the fins 1120 need not necessarily extend above the member 1110 along all their length.

**[00115]** Clearly there are other ways of arranging for clamping the substrate support SS to the mirror block MB whilst ensuring that the parts of the clamp for holding the substrate support SS substantially stationary in the plane perpendicular to the optical axis are substantially mechanically de-coupled from the mirror block in the direction of the optical axis. Other types of clamp can be used and the mirror block may have its position measured by means other than an inferometers INF and mirrors 1150 and could be referred to just as a block.

**[00116]** While specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. For example, the invention may take the form of a computer program containing one or more sequences of machine-readable instructions describing a method as disclosed above, or a data storage medium (e.g. semiconductor memory, magnetic or optical disk) having such a computer program stored therein.

**[00117]** The present invention can be applied to any immersion lithography apparatus, in particular, but not exclusively, those types mentioned above.

**[00118]** The descriptions above are intended to be illustrative, not limiting. Thus, it will be apparent to one skilled in the art that modifications may be made to the invention as described without departing from the scope of the claims set out below.

WHAT IS CLAIMED IS:

1. A lithographic apparatus comprising:

a projection system constructed to project a beam of radiation onto a target portion of a substrate;

a patterning device constructed to impart a cross-section of said beam of radiation with a pattern; and

a chuck system including,

a chuck constructed to hold one of said substrate and said patterning device;

a frame constructed to hold said chuck; and

a chuck support structure operable between said chuck and said frame, and constructed to support said chuck relative to said frame, said chuck support structure including a flexure element coupled between said chuck and said frame, said flexure element being flexible in at least one degree of freedom.

2. A lithographic apparatus according to claim 1, wherein

said flexure element is resistant to deformation in a plane parallel to a direction in which said frame is movable.

3. A lithographic apparatus according to claim 1, wherein

said chuck support structure extends in a spacing between said chuck and said frame.

4. A lithographic apparatus according to claim 3, wherein

said flexure element extends at least partially in said spacing.

5. A lithographic apparatus according to claim 1, wherein

said chuck support structure is resistant to deformation in a direction in which said flexure element is flexible.

6. A lithographic apparatus according to claim 1, wherein said chuck support structure is mechanically disconnected and separate from at least one of said frame and said chuck.

7. A lithographic apparatus according to claim 1, further comprising:
a chuck deformation prediction device constructed to predict a deformation of said chuck in at least one degree of freedom; and
a projection adjustment device connected to said chuck deformation prediction device, said projection adjustment device being constructed to adjust in response to a prediction signal outputted by said chuck deformation prediction device at least one of a property of said beam of radiation and a position of a pattern in said patterned beam of radiation relative to said object.

8. A lithographic apparatus according to claim 1, wherein said frame has a recess and said chuck is positioned in said recess.

9. A lithographic apparatus according to claims 1, further comprising:
an illumination system constructed to provide said beam of radiation;
a patterning device support structure constructed to support said patterning device; and
a substrate table for holding said substrate;
at least one of said patterning device support structure and said substrate table including said chuck system.

10. A method of manufacturing a device, comprising:
projecting a beam of radiation onto a target portion of a substrate;
imparting a pattern to a cross-section of the beam of radiation to form a patterned beam using a patterning device; and
supporting at least one of the substrate and the patterning device in a flexible manner by using a chuck system, the chuck system including a chuck to hold one of the

substrate and the patterning device and a frame to hold the chuck, and providing flexible support in at least one degree of freedom between the chuck and the frame.

11. A method according to claim 10, further comprising:

predicting deformation of the chuck; and

adjusting one of a property of the beam of radiation and a position of a pattern in the patterned beam in response to the predicted deformation of the chuck.

12. A chuck system constructed to support an object in a lithographic apparatus, said chuck system comprising:

a chuck constructed to hold the object;

a frame constructed to hold said chuck; and

a chuck support structure operable between said chuck and said frame and constructed to support said chuck relative to said frame,

said chuck support structure including a flexure element, said flexure element being coupled between said chuck and said frame, and said flexure element being flexible in at least one degree of freedom.

13. A chuck system according to claim 12, wherein

said object is one of a substrate and a patterning device constructed to impart a cross-section of a beam of radiation with a pattern.

14. A lithographic apparatus comprising:

means for projecting a beam of radiation onto a substrate;

means for forming a patterned beam of radiation by imparting a cross-section of said beam of radiation with a pattern; and

flexible means for supporting one of said substrate and said means for forming a patterned beam in a flexible manner to provide at least one degree of freedom.

15. A lithographic apparatus comprising:

- a substrate table comprising a frame for receiving a substrate support constructed to support a substrate; and
- a clamp on said frame for holding said substrate support substantially stationary relative to said frame;
- wherein parts of said clamp for holding said substrate support substantially stationary, in the plane perpendicular to the optical axis, relative to said frame are substantially mechanically decoupled from said frame in the direction of the optical axis.

16. The lithographic apparatus of claim 15, wherein parts of said clamp for holding said substrate support substantially stationary in the direction of the optical axis comprise three hinges.

17. The lithographic apparatus of claim 16, wherein said hinges comprise projections on a surface of said frame or said substrate support.

18. The lithographic apparatus of claim 15, wherein parts of said clamp for holding said substrate support in the direction of the optical axis are stiffly mounted to said frame.

19. The lithographic apparatus of claim 15, wherein said parts of said clamp for holding said substrate support substantially stationary in the plane perpendicular to the optical axis comprise a flexible member which is brought into contact with a lower surface of said substrate support.

20. The lithographic apparatus of claim 19, wherein said member is brought into contact with said lower surface by application of an underpressure.

21. The apparatus of claim 19, wherein said substrate table further comprises a

substrate support and wherein said substrate support is at least 10 times as stiff in the direction of the optical axis as said flexible member.

22. The apparatus of claim 19, wherein said parts of said clamp for holding the substrate support substantially stationary in the direction of the optical axis comprise three projections on said member or on said substrate support.

23. The apparatus of claim 22, wherein said projections are mechanically coupled to said frame.

24. The apparatus of claim 23, wherein said mechanical coupling comprises ribs extending out of said member in a direction away from said substrate support and connected to said frame.

25. The apparatus of claim 19, wherein a plurality of slits extending through the member make it flexible.

26. The apparatus of claim 17, wherein said hinges operate by allowing rotation of said projections in the plane perpendicular to the optical axis.

27. The apparatus of claim 17, wherein said hinges each comprise a projection on said frame and only a localised area for contact with said projection on said substrate support.

28. A lithographic apparatus comprising:

- a substrate table comprising a frame for receiving and supporting a substrate support which is constructed to hold a substrate;
- wherein said frame is arranged to support said substrate support in the direction of the optical axis by three mechanical hinges.

29. The apparatus of claim 28, wherein said block comprises a clamp for holding said substrate support substantially stationary relative to said frame.

30. The apparatus of claim 29, wherein said clamp comprises a member which is brought into contact with an underside of said substrate support to hold said substrate support.

31. The apparatus of claim 24, wherein said member is relatively stiff in the plane perpendicular to the optical axis and relatively flexible in the direction of the optical axis.

32. A lithographic apparatus comprising:

- a substrate table;
- said substrate table comprising:
- a substrate support constructed for holding a substrate; and
- a frame for receiving said substrate support;
- wherein said frame has a member for supporting said substrate support, said member being less stiff in the direction of the optical axis than said substrate support.

33. The apparatus of claim 32, wherein said member has discrete areas which are stiff in the direction of the optical axis, said discrete areas and said substrate support being constructed such that said substrate support is effectively supported at three points.

34. The apparatus of claim 33, wherein interaction between said substrate support and said three points is mechanically equivalent to a hinge.

35. The apparatus of claim 32, wherein said member is a membrane.

36. The apparatus of claim 32, wherein said member comprises slits which are effective to make said member less stiff in the direction of said optical axis than said substrate support.

37. A device manufacturing method comprising transferring a pattern from a patterning device onto a substrate, wherein said substrate is supported on a substrate support which is stiffer in the direction from which said pattern is transferred than a member of a frame on which said substrate support is held.

38. A lithographic apparatus comprising:

- a substrate table;
- a positional controller for controlling the position of said substrate table;
- said substrate table comprising:
- a substrate support constructed for holding a substrate; and
- a frame for receiving said substrate support and constructed to support said substrate support in the direction of the optical axis and decoupled from said substrate support in the plane perpendicular to the optical axis;
- wherein said positional controller compensates for expansion and/or contraction of said substrate support due to temperature changes of said substrate support.

39. The apparatus of claim 38, further comprising an exposure controller which compensates for expansion and/or contraction of said substrate support due to temperature changes of said substrate support.

40. A device manufacturing method comprising transferring a pattern from a patterning device onto a substrate, wherein said substrate is supported on a substrate support which is itself supported in a first direction from which said pattern is transferred by a frame from which it is decoupled in the plane perpendicular to said first direction and wherein

a positional controller compensates for expansion and/or contraction of said substrate support due to temperature changes of said substrate support.

41. The method of claim 40, further comprising adjusting exposure settings to compensate for expansion and/or contraction of said substrate support due to temperature changes of said substrate support.

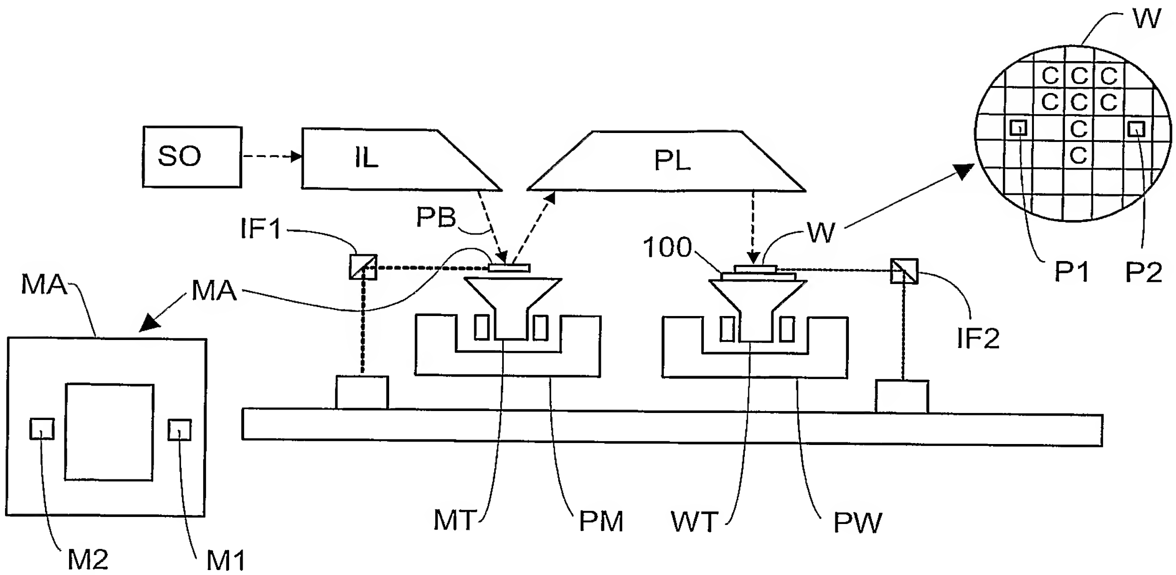
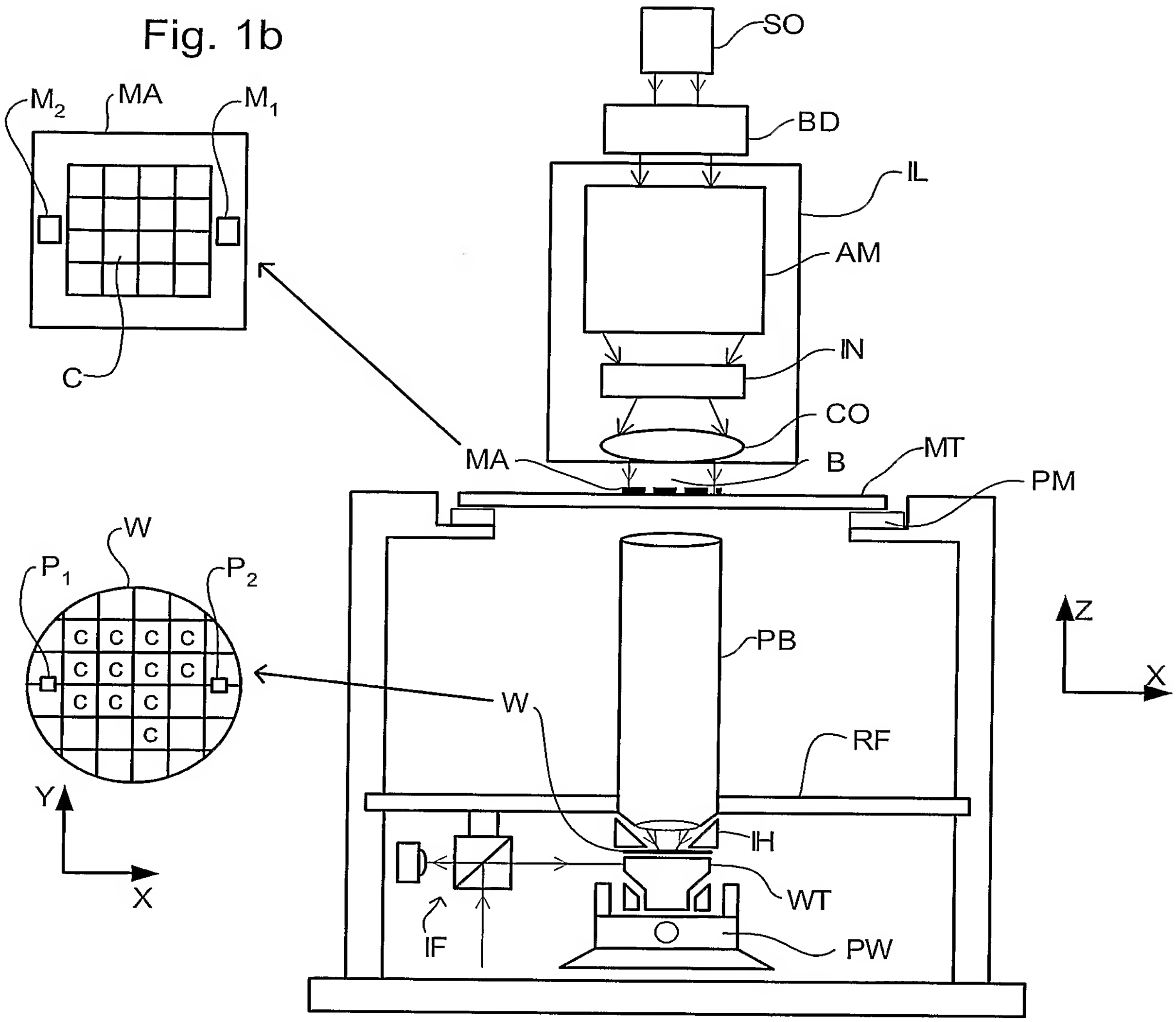
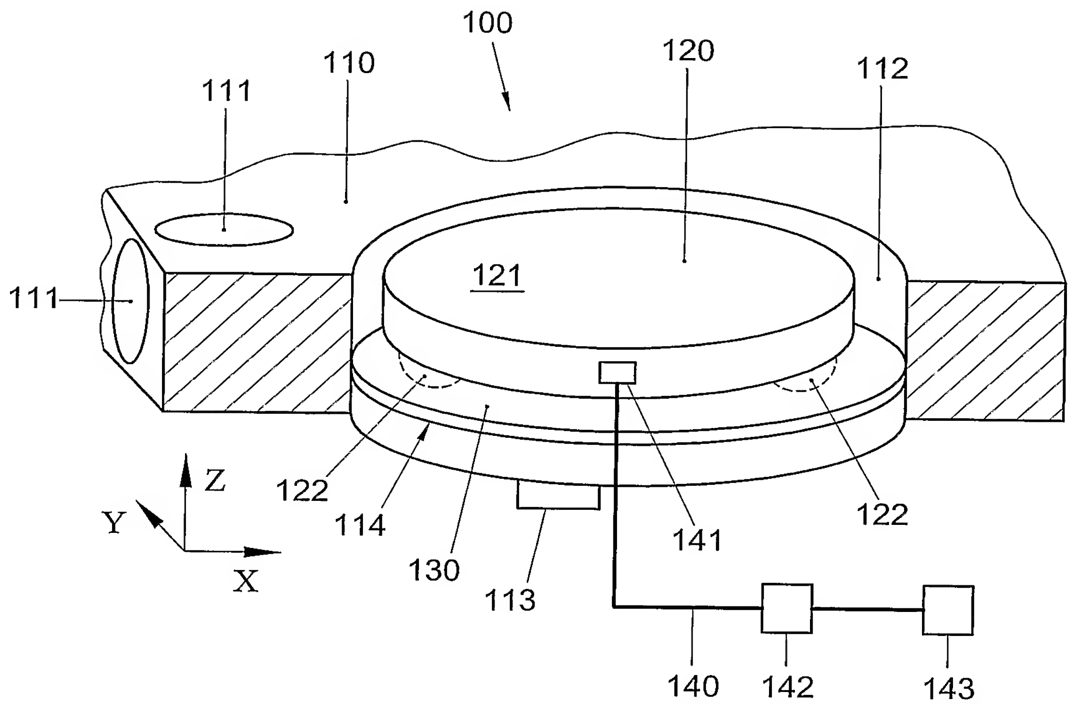



Fig. 1a

Fig. 1b

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143

Fig. 2

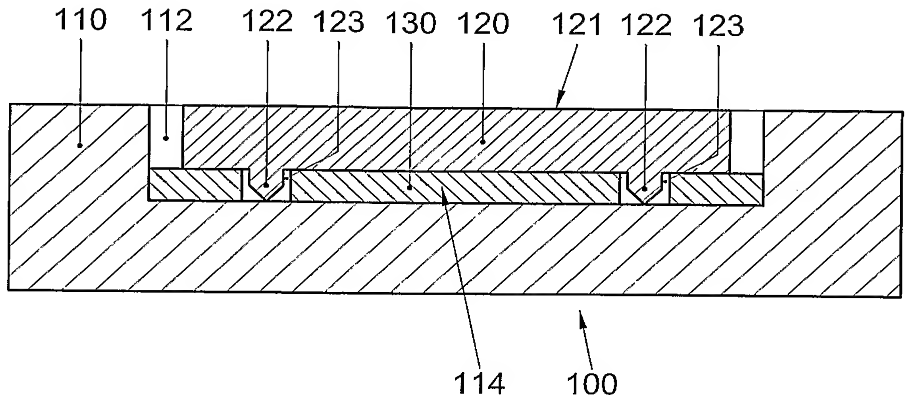
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Fig. 3

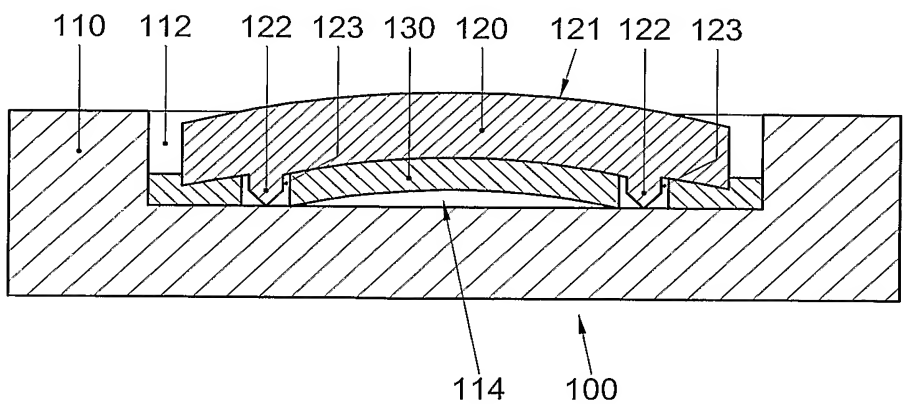
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Fig. 4

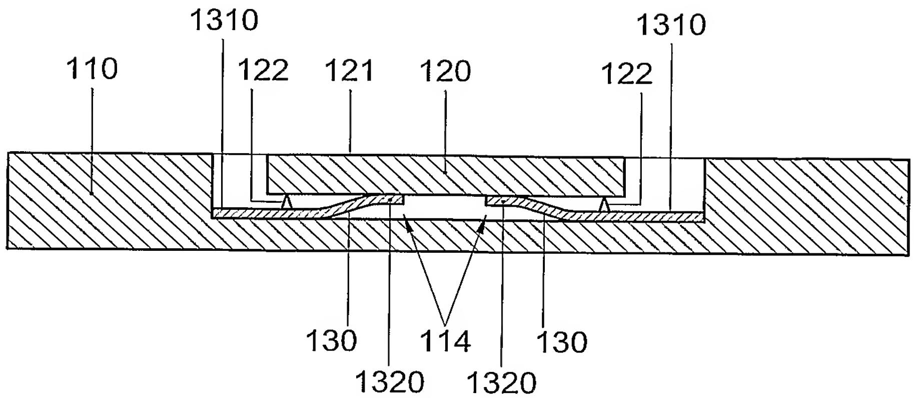
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Fig. 5

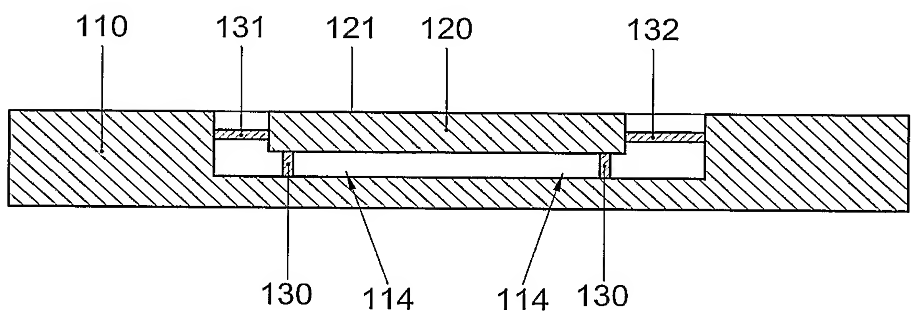
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Fig. 6

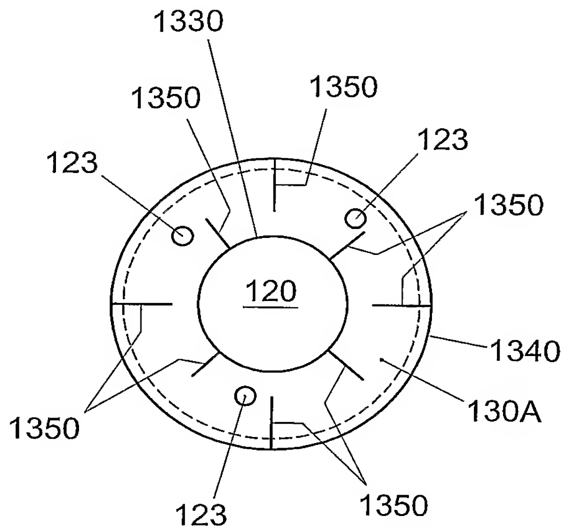


Fig. 7A

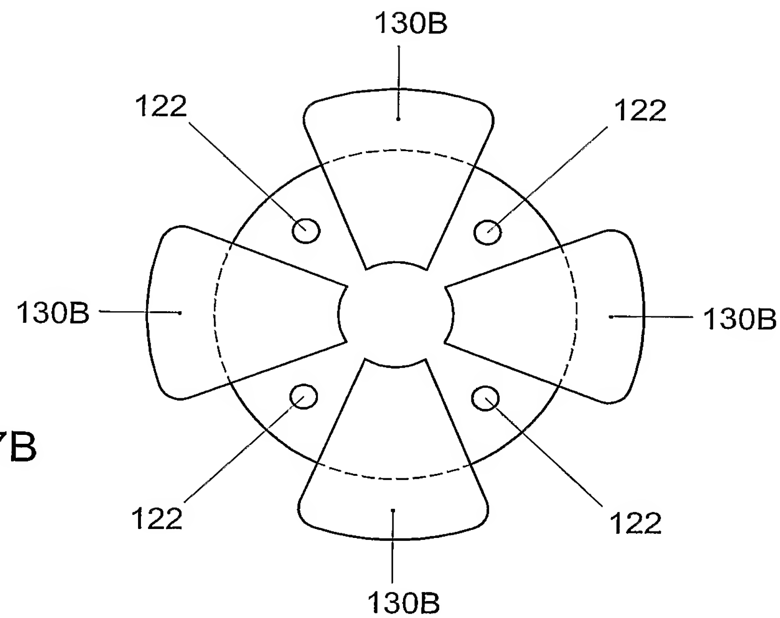


Fig. 7B

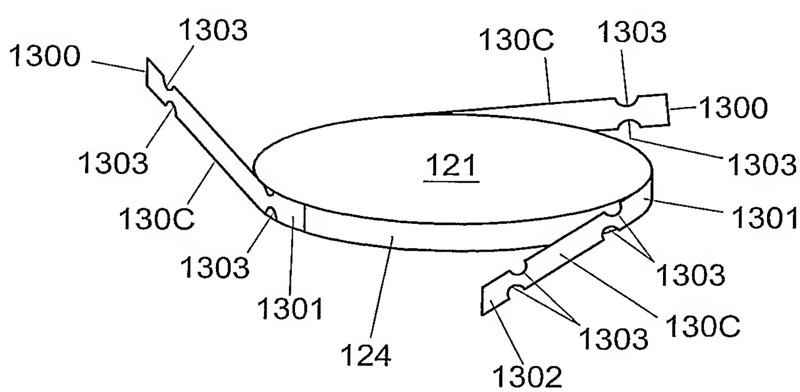


Fig. 7C

Fig. 8

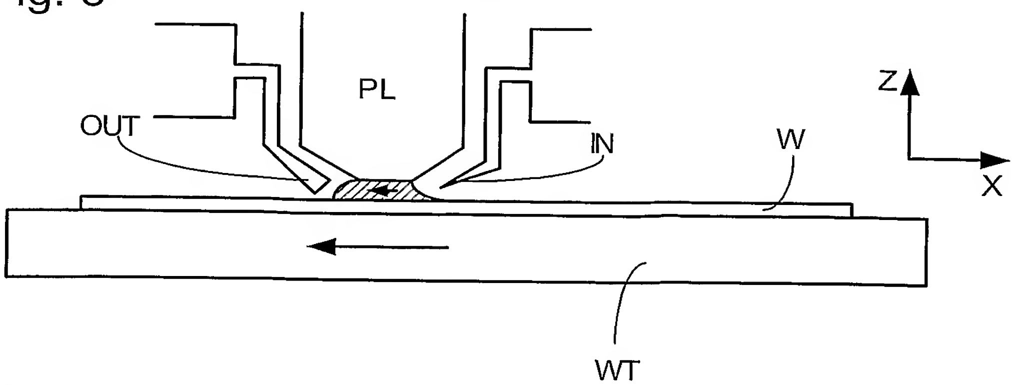


Fig. 9

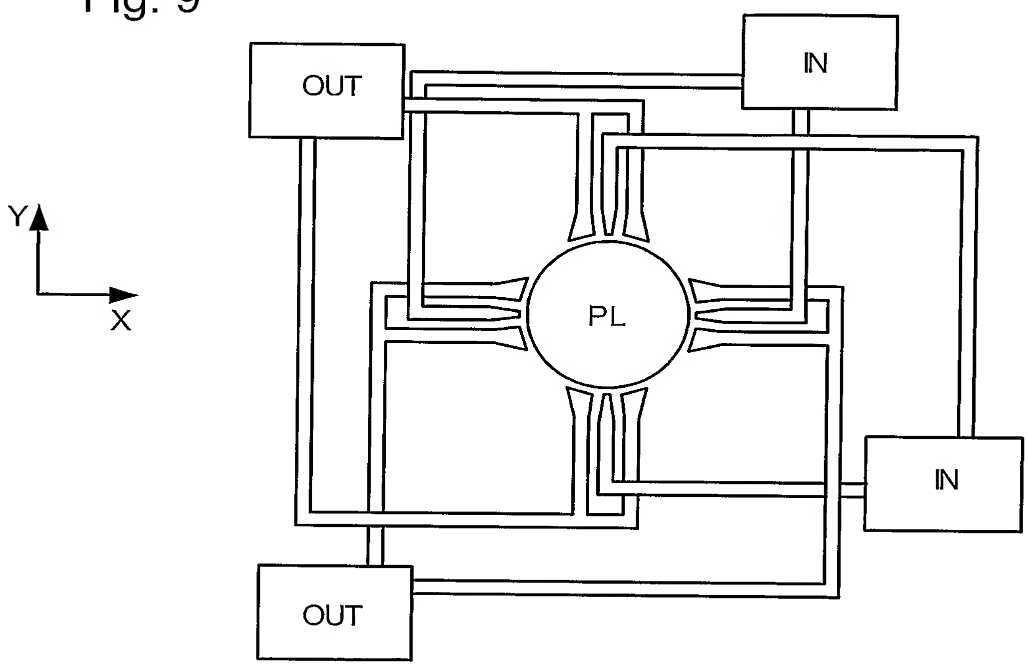


Fig. 10

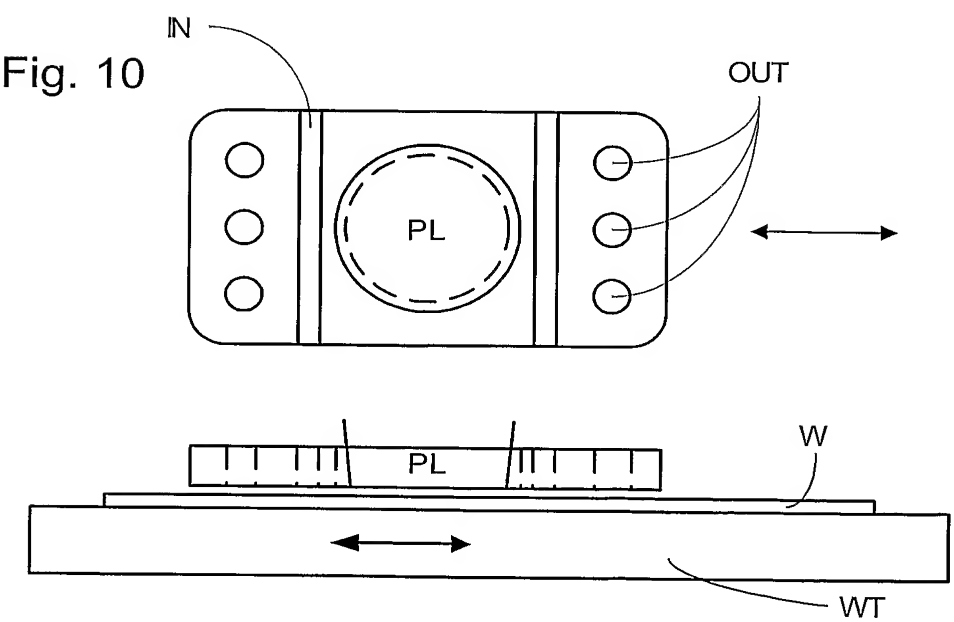

Fig. 11

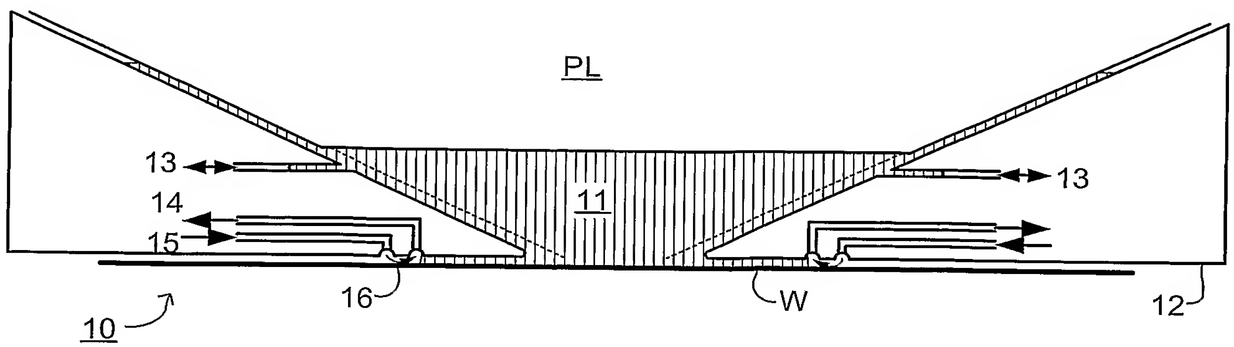


Fig. 12

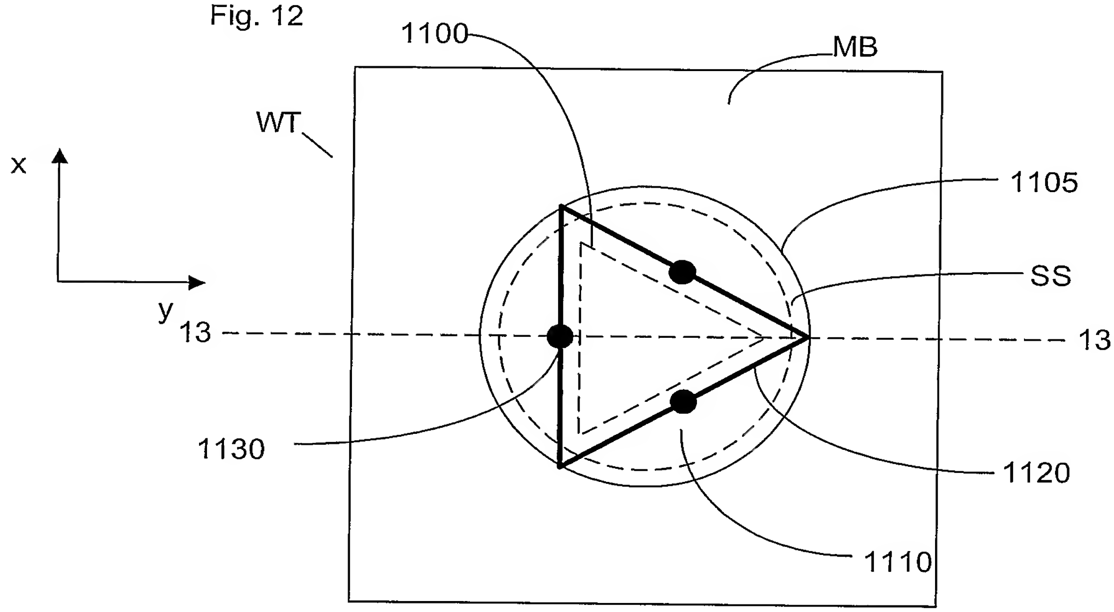


Fig. 13

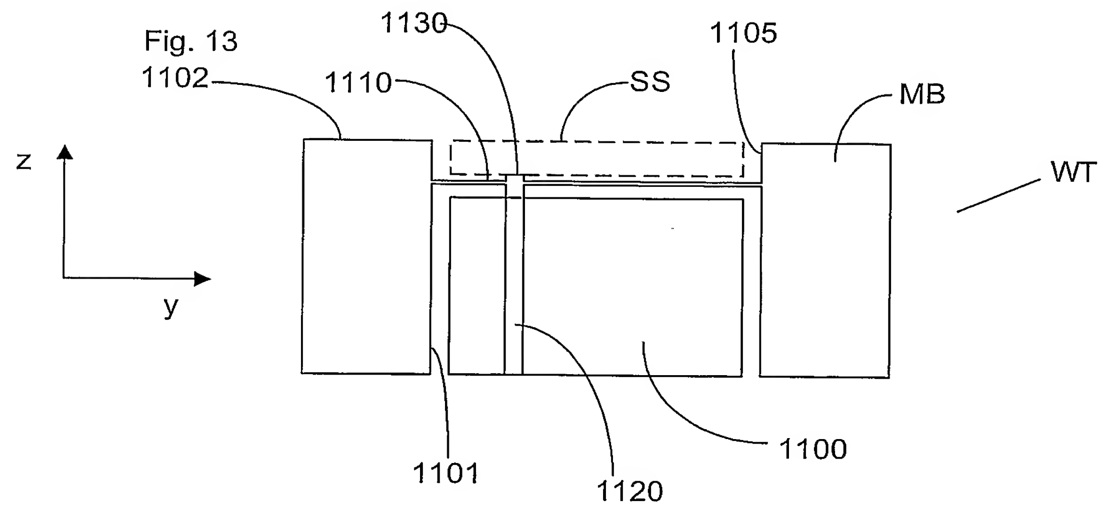

Fig. 14

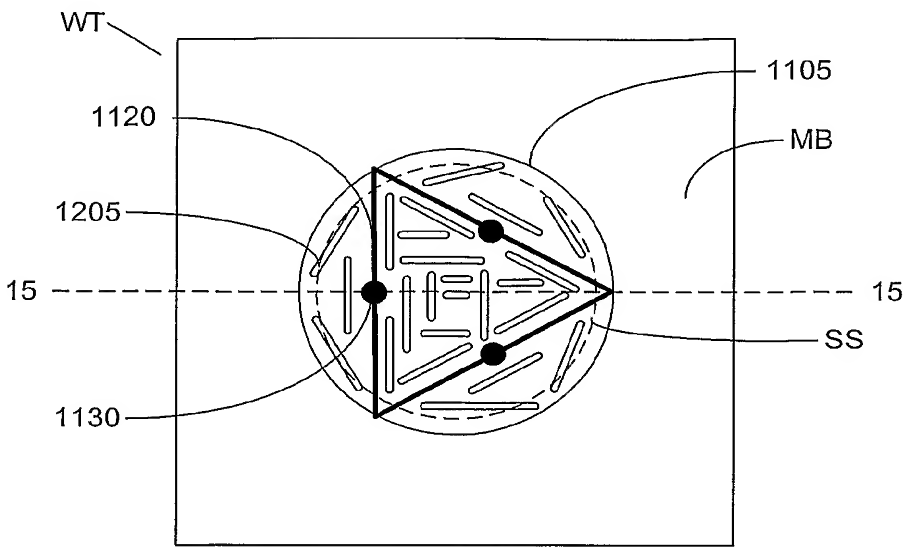


Fig. 17

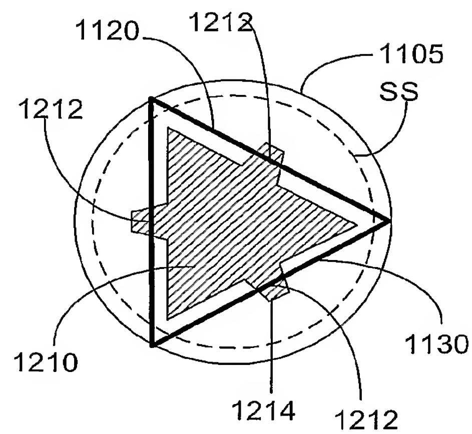


Fig 15

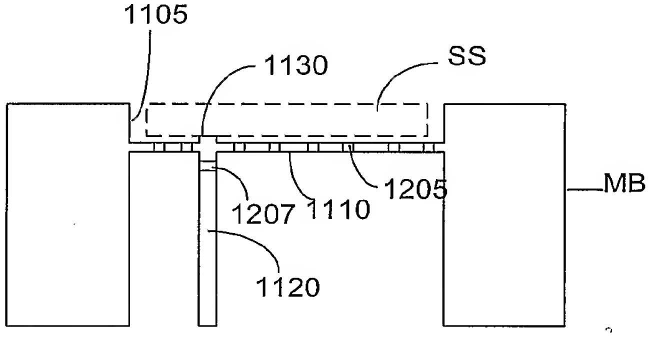


Fig. 16

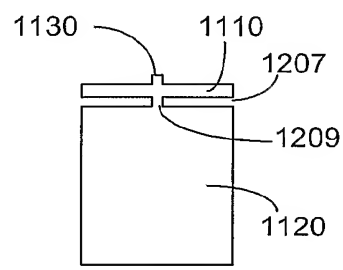


FIG. 18